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(71) Applicant *(for all designated States except US)*: CRUMAX MAGNETICS, INC. [US/US]; 110 Terry Drive, Newtown, PA 18940 (US).

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(75) Inventors/Applicants *(for US only)*: AMBROSE, Jennifer, M. [US/US]; 546 Cedar Hollow Drive, Yardley, PA 19067 (US). KING, Jonathan, D. [US/US]; 3455 Street Road, Livingston #11, Bensalem, PA 19020 (US). CALLIHAN, Randolph, W. [US/US]; 546 Cedar Hollow Drive, Yardley, PA 19067 (US).

(74) Agent: JOHNSON, Kristin, L.; Kilpatrick Stockton LLP, Suite 2800, 1100 Peachtree Street, Atlanta, GA 30309-4530 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European

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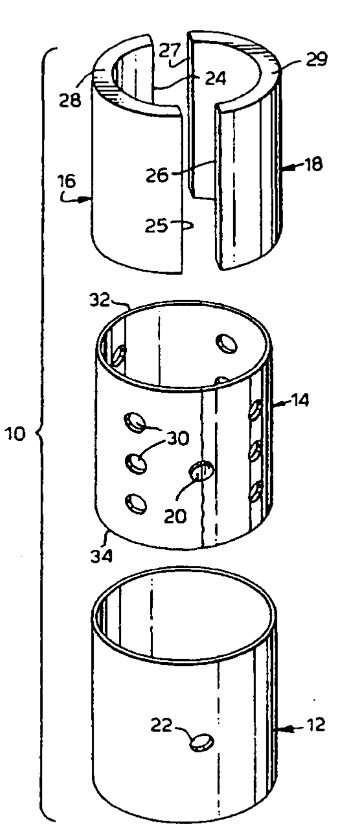
(54) Title: PERMANENT MAGNET STATOR ASSEMBLY AND METHOD OF MANUFACTURING



(57) Abstract: A motor stator (12) having increased flux-carrying capacity and a method of increasing the flux-carrying capacity is described; a sleeve (14) of ferro-magnetic material is first inserted into housing (12) of ferro-magnetic material, thereby increasing the thickness, and consequently the flux-carrying capacity, of the housing, a mixture of plastic and magnet powder is then injection moulded into the housing/sleeve and passes through perforations (30) located in the sleeve to adhere to both the sleeve and the housing and form arcuate magnet segments (16, 18); resulting in stronger adhesion between the magnets and the housing/sleeve and increased flux-carrying capacity of the steel behind the magnets.

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patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

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AMENDED CLAIMS

[received by the International Bureau on 7 February 2002 (07.02.02);
original claims 1-16 replaced by amended claims 1-13 (2 pages)]

1. A stator comprising:
   a. a housing (12) of ferro- magnetic material;
   b. at least one magnet (16,18) located within the housing;
   c. a sleeve (14) is nested between the housing (12) and the magnet (16,18)

   characterised in that

   d. the sleeve is a band (14) of ferro-magnetic material having perforations (30);

      and,

   e. the at least one magnet (16,18) is a moulding extending through the sleeve perforations (30).

2. A stator as claimed in claim 1 **and further characterised in that** the sleeve (14) is fixed to the housing (12).

3. A stator as claimed in claim 1 or claim 2 **and further characterised in that** the housing (12) is steel.

4. A stator as claimed in any of claims 1 to 3 **and further characterised in that** the sleeve (14) has a protrusion (20) located in a hole (22) in the housing (12).

5. A stator as claimed in any of claims 1 to 4 **and further characterised in that** the axial heights of the magnet (16,18) and the sleeve (14) are approximately equal.

6. A stator as claimed in any of claims 1 to 5 **and further characterised in that** two magnets (16,18) are fixed within opposing sides the sleeve (14).

7. A stator as claimed in any of claims 1 to 6 **and further characterised in that** the magnet longitudinal edges (24,25,26,27) comprise a more coercive material than the centre portions (28,29) thereof.

8. A stator as claimed in claim 7 **and further characterised in that** the magnet centres portions (28,29) comprise a non-magnetic material.

9. A stator as claimed in claim 8 **and further characterised in that** the nonmagnetic material comprises plastic.

10. A stator as claimed in any of claims 1 to 9 **and further characterised in that** plastic spacers are located between opposed edges (24,25,26,27) of opposing magnets (16,18).

11. A stator as claimed in any of claims 1 to 10 **and further characterised in that** magnet material extends through the sleeve perforations (30) to adhere to the housing (12).

12. A method of manufacturing a stator comprising the steps of:-
    a. locating at least one magnet (16,18) within a housing (12) of ferro-magnetic material;
    b. nesting a sleeve (14) between the housing and the at least one magnet;

    characterised:-

    c. **in that** the sleeve (14) is a band of ferro-magnetic material having perforations (30);
    and,
    d) **by the step of** moulding the at least one magnet (16,18) to extend through the sleeve perforations.

13. The method of claim 11 **and further characterised by the step of** moulding a mixture comprising plastic powder and magnetic powder within the sleeve (14) to form the at least one magnet (16,18).

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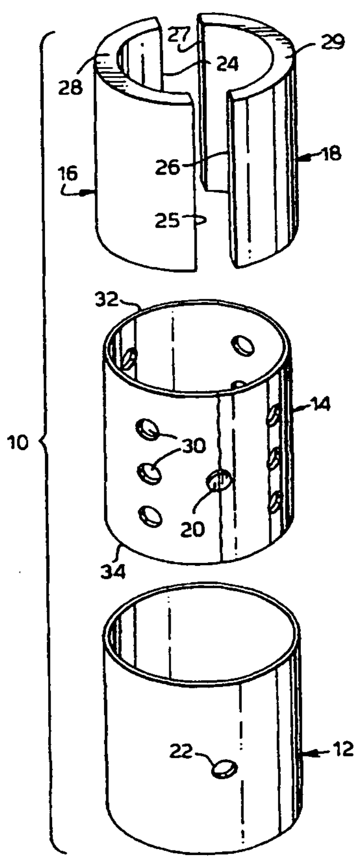

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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y A	US 4 110 718 A (ODOR FRANK ET AL) 29 August 1978 (1978-08-29) abstract; figure 1	9 10,11
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 November 2001	10/12/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Zanichelli, F

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International Application No
PCT/IB 01/00724

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IB 01/00724

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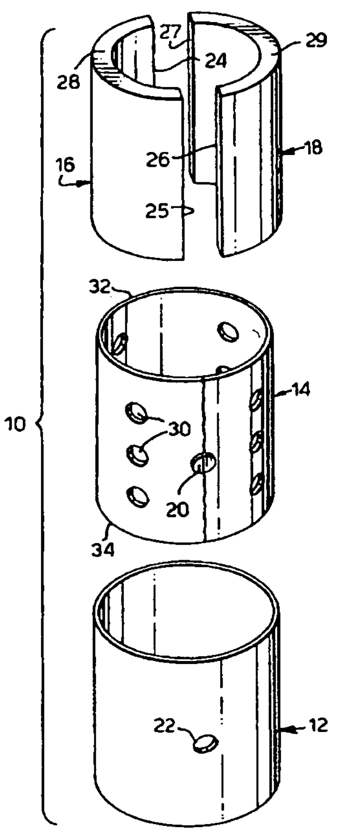

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Permanent Magnet Stator Assembly and Method of Manufacturing.

This invention relates a permanent magnet stator and to manufacturing stators; preferably, but not exclusively, for electric motors.

Permanent magnet stators produce a magnetic field that interacts with the electromagnetic armature field, thereby producing torque. This interaction between the two fields results in rotation of the armature, also referred to as the rotor. Some stators typically comprise one or more pairs of arcuate magnetic segments positioned and secured in a hollow cylindrical housing of ferro-magnetic material. The housing attracts and completes the flux lines (hereinafter referred to as "carrying" or "capturing" the flux) produced by and between the alternating north and south poles of the magnets.

The magnets of many stators have traditionally been mounted to the housing using adhesive applied to the inner wall of the housing and/or to the outer surface of the magnets, or, alternatively, mechanical locking means such as clips or springs. Document US-A-5,216,306 discloses mechanically fixing the magnet in the housing and has the object of the invention of reducing the weight of a motor by manufacturing the outer cylinder of the motor casing of the motor from a non-ferro-magnetic material, as opposed to the traditional ferro-magnetic material. A thin iron or other +ferro-magnetic material inner cylinder is fitted inside the outer cylinder, thereby providing the necessary magnetic material without significantly increasing the weight of the casing. The magnets are then fitted in the inner cylinder with magnet holders.

Such mechanical locking means, as well as adhesives, require positioning and handling of both the housing and the magnets which, in addition to requiring fixing and handling systems and processes, can lead to performance and reliability problems. The magnets, most often ceramic ferrite, can chip or break during insertion into the housing, resulting in motor failure. Additionally, damage can occur to the other motor components when the manufacturer is attempting to insert and properly affix the magnets to the housing. Traditional means used to secure the magnets are vulnerable to mechanical wear and eventually can fail. Failure of the adhesive or

mechanical retention of springs or clips results in magnet movement relative to the housing. If the magnets are no longer properly aligned, fewer flux lines are produced, resulting in a weaker magnetic field and consequent performance reduction and/or premature motor failure.

In addition to these problems resulting from the poor retention of magnets in the housing known housings are less effective stators. The housing carries the flux produced by the magnets and, the thicker the (steel) housing, the greater its flux carrying capacity. If the housing is not sufficiently thick it may not have the capacity to carry all of the flux lines produced by the magnets; the housing will become and saturated by the flux and some flux will leak; leading to weaker magnetic fields and non-optimum motor performance.

Consequently, designers desiring to use higher energy magnets in motors, such as Rare Earth Magnets including Neodymium Iron Boron (NdFeB) and Samarium Cobalt (SmCo), need thicker housings to capture the increased flux produced by these magnets. Unfortunately, constraints on the size of the housing and limitations inherent in traditional manufacturing processes result in housings too thin to carry the flux of these higher energy magnet materials. Therefore, regardless of the size of the magnets used, traditional housings are only capable of carrying a limited amount of flux. The increased flux produced by these higher energy magnets is consequently lost, thereby eliminating the desired benefit (increased motor performance) of using such magnets. Designers, therefore, simply resort to using the lower energy magnets.

Document GB-A-2308017 discloses a ring made of steel material disposed so as to abut against field core claws, resin permanent magnets are moulded onto the ring and to abut between the claws. Document EP-A-0168743 discloses a stator having a tubular yoke or housing with an annular or ring-segmental plastic magnet injection moulded or pressed onto the inside of the yoke.

It is an object of the present invention to provide a permanent magnet stator that overcomes the above-stated problems by providing improved mechanical retention and/or increased flux carrying capability of magnets in a housing of ferro-magnetic material .

According to the present invention, a stator comprises a housing of ferro-magnetic material, at least one magnet located within the housing and a sleeve of ferro-magnetic material nested between the housing and the magnet. The sleeve increases the thickness and, consequently, the flux-carrying capacity of the housing

According a first embodiment of the present invention, the sleeve is fixed to the housing, which may be of steel.

According to a second embodiment of the present invention, the sleeve has a protrusion located in a hole in the housing.

According to a third embodiment of the present invention, the at least one magnet is a moulding.

According to a fourth embodiment of the present invention, the sleeve has perforations.

According to a fifth embodiment of the present invention, longitudinal magnet edges comprise a more coercive material than magnet centre portions; which may comprise a non-magnetic material such as plastic.

Also according to the present invention, a method of manufacturing a stator comprises locating at least one magnet within a housing of ferro-magnetic material and nesting a sleeve of ferro-magnetic material between the housing and the magnet.

According to a first embodiment of the method of the present invention comprises moulding a mixture comprising plastic powder and magnetic powder within the sleeve to form the at least one magnet; portions of the magnet may be moulded through perforations in the sleeve. The perforations allow the mixture to pass through parts of the sleeve, forming a mechanical lock resulting in stronger retention of the magnets in the housing/sleeve.

The stator of the present invention addresses the problems of previous stators by providing:-

1) a stator with a thicker housing and magnets more securely affixed to the housing,
2) an automated method of inserting the magnets into the housing, and
3) a thicker housing that will allow for effective use of higher energy magnets, thereby decreasing the occurrence of both loss of flux and physical damage to the stator components without significantly increasing the cost of production of the stator.

The above and other features of the present invention are illustrated by way of example in the Drawings, wherein:-

Fig. 1 is an exploded perspective view of a two permanent magnet stator in accordance with an embodiment of the present invention;

and,

Fig. 2 is a perspective view of the assembled stator of Fig. 1.

As shown by the drawings, a stator 10 includes a cylindrical housing 12 of ferro-magnetic material, a cylindrical inner sleeve 14 of ferro-magnetic material and a pair of arcuate or part cylindrical, segmental magnets 16 and 18; the stator could contain more than one magnet pair, only one pair is shown for ease of illustration. The inner sleeve 14 is first inserted into the housing 12 to nest therein. The sleeve 14 may be a continuous or discontinuous band. If the sleeve 14 is a discontinuous band it can have an outer diameter equal or greater to the diameter of the inner wall of the housing 12 so that the inserted sleeve 14 will naturally tend to expand and bear against the inner wall of the housing 12. Regardless of whether the sleeve 14 is a continuous or discontinuous band, the sleeve 14 may be fixed to the housing. For example, spot welding, glue or any other mechanical locking means may be used to fix and reinforce the sleeve 14 in the housing 12. Moreover, a protrusion 20 may be provided on the outside of the sleeve 14 to complement a hole 22 in the housing 12. Alignment of the protrusion 20 into the hole 22 further locks the sleeve 14 into place. The housing 12 and sleeve 14 may be made from steel or soft iron any other type of of ferro-magnetic material.

Once the sleeve 14 is in place, the magnets 16, 18 are inserted into the subassembly of housing 12 and sleeve 14 by injection moulding. A suitable powder and a suitable plastic powder are mixed and heated until the plastic becomes molten. The molten magnet mixture is then injection moulded into the sleeve 14 and hardens almost instantaneously to form arcuate magnetic segments 16, 18. The intended height of the sleeve 14 and the magnets 16, 18 are preferably (although not necessarily) equal, so that open ends 32, 34 of the sleeve 14 can provide physical stops for an injection mould; the mould abutting the sleeve ends 32, 34 and being further shaped to create a cavity into which the molten mixture is injected to form the magnets 16, 18.

While the magnets 16, 18 may be moulded from the same magnetic material, a reduction in the cost of manufacture may be attained by using a two component moulding process, whereby longitudinal edge portions 24, 25, 26, 27 of the magnets 16, 18 are moulded from a higher coercively material than the centre portions 28, 29. The higher the coercively of a material, the greater its resistance to demagnetisation, and often the more expensive it is.

Alternatively, because a centre portion, 10-20° of the arcuate centre portion of 28, 29 of each magnet 16, 18, does not contribute to motor performance; that portion could be moulded from a cheaper, less-magnetic or non-magnetic material, a thinner magnet or eliminated altogether to further reduce the cost of manufacture.

After the molten mixture is injected into the sleeve 14, perforations 30 located in the sleeve 14 allow the molten mixture to pass through the sleeve 14 and directly contact the inner wall of the housing 12, thereby providing maximum magnet retention in the housing 12. Magnet retention may be further enhanced by moulding non-magnetic plastic spacers between the opposed edges 24, 25, 26, 27 of the magnets 16, 18. These plastic spacers can also be used to marry the stator with other motor components, such as brush carriers or bearing holders.

Insertion of the sleeve 14 into the housing 12 allows increased thickness of the housing 12 in the critical locations behind the magnets 16, 18; thereby enabling the housing 12 to capture all or more of the flux produced by the magnets 16, 18, without the need to employ a more costly manufacturing process to produce thicker housings. Moreover, because the sleeve-reinforced housing 12 is equipped to carry more flux, higher energy magnets of the same physical size can be used without waste of flux. This results in increased performance of the stator 10, and consequently the motor, without increasing the size of the magnets 16, 18 or the cost of manufacturing the stator 10. Finally, injection moulding the magnet arcs 16, 18 into the housing 12 eliminates the potential failure modes of the stator components resulting from mishandling of the magnet arcs 16, 18 as well as retention problems of the magnet arcs 16, 18 in the housing 12.

In a bi-directional motor, the edge portions 24, 25, 26, 27 bear the brunt of the demagnetisation force and therefore require a higher coercively material than the centre portions 28, 29. Therefore, using the more coercive material only where it is really needed (at the edge portions 24, 25, 26, 27) and using a less expensive, lower coercively material at the centre portions 28, 29 of the magnets 16 anf 18 results in significant economies of manufacture.

For uni-directional motors, the leading edge of the magnets could be moulded of a higher remanence material to increase the flux linkages and thereby motor performance. The trailing edges could still be moulded of the higher coercively material to resist demagnetisation.

Claims:

1. A stator comprising:
   a. a housing (12) of ferro- magnetic material;
   b. at least one magnet (16,18) located within the housing;

   characterised in that

   c. a sleeve (14) of ferro- magnetic material is nested between the housing (12) and the magnet (16,18).

2. A stator as claimed in claim 1 **and further characterised in that** the sleeve (14) is fixed to the housing (12).

3. A stator as claimed in claim 1 or claim 2 **and further characterised in that** the housing (12) is steel.

4. A stator as claimed in any of claims 1 to 3 **and further characterised in that** the sleeve (14) has a protrusion (20) located in a hole (22) in the housing (12).

5. A stator as claimed in any of claims 1 to 4 **and further characterised in that** the at least one magnet (16,18) is a moulding.

6. A stator as claimed in claim 5 **and further characterised in that** the sleeve (14) has perforations (30).

7. A stator as claimed in any of claims 1 to 6 **and further characterised in that** the axial heights of the magnet (16,18) and the sleeve (14) are approximately equal.

8. A stator as claimed in any of claims 1 to 7 **and further characterised in that** two magnets (16,18) are fixed within opposing sides the sleeve (14).

9. A stator as claimed in any of claims 5 to 8 **and further characterised in that** the longitudinal edges (24,25,26,27) of each magnet (16,18) comprise a more coercive material than the centre portion (28,29) of each magnet.

10. A stator as claimed in claim 9 **and further characterised in that** the magnet centres portions (28,29) comprise a non-magnetic material.

11. A stator as claimed in claim 10 **and further characterised in that** the nonmagnetic material comprises plastic.

12. A stator as claimed in any of claims 5 to 10 **and further characterised in that** plastic spacers are located between opposed edges (24,25,26,27) the opposing magnets (16,18).

13. A stator as claimed in any of claims 4 to 10 **and further characterised in that** magnet material extends through the sleeve perforations (30) to adhere to the housing (12).

14. A method of manufacturing a stator comprising locating at least one magnet (16,18) within a housing (12) of ferro- magnetic material **characterised by the step of** nesting a sleeve (14) of ferro- magnetic material between the housing (12) and the magnet.

15. The method of claim 14 **and further characterised by the step of** moulding a mixture comprising plastic powder and magnetic powder within the sleeve (14) to form the at least one magnet (16,18).

16. The method of claim 15 **and further characterised by the step of** moulding the mixture through perforations (30) in the sleeve (14).

Fig.1.

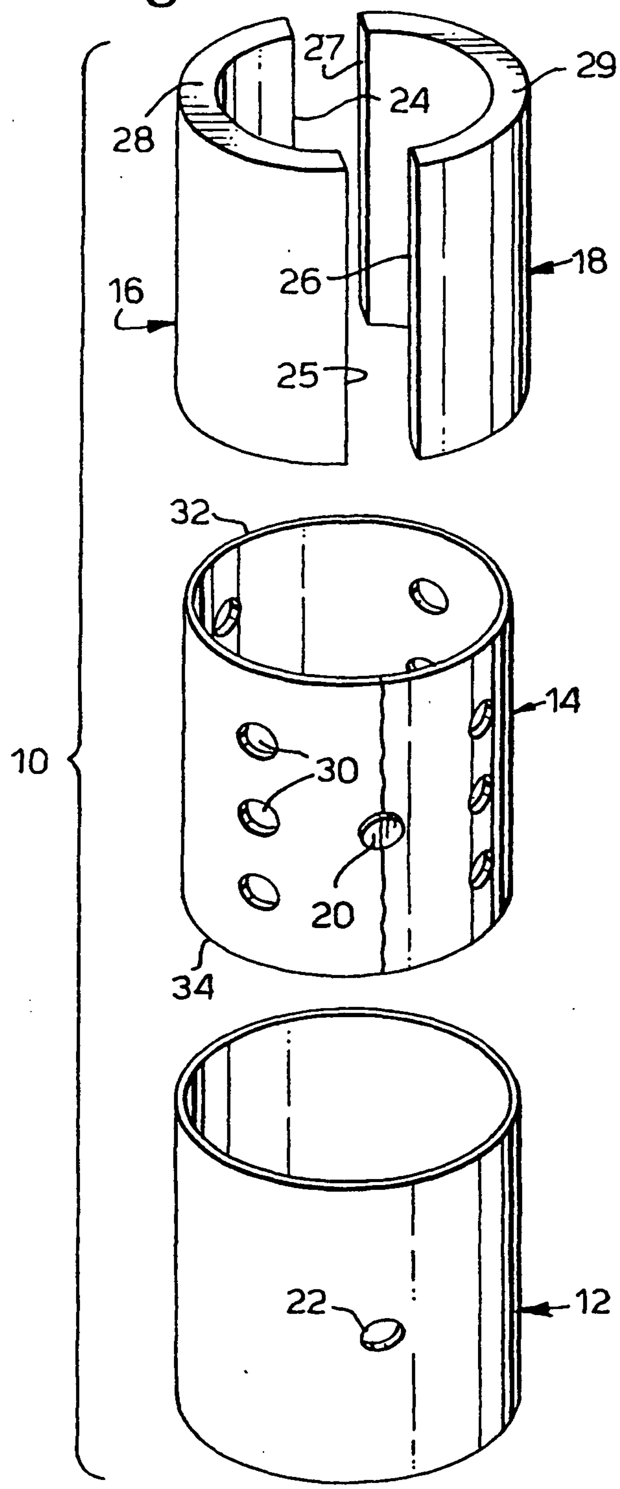
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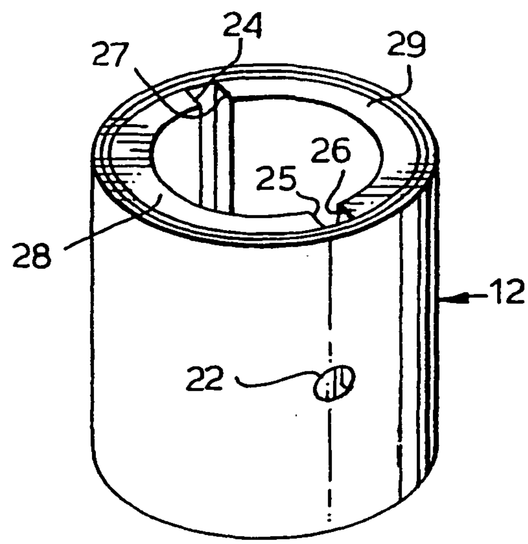
Fig.2.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